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"Gamma Ray Astronomy"

FINAL REPORT

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Prepared by

Dr. William S. Paciesas

Prepared for
George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812

Submitted by
Department of Physics
The University of Alabama in Huntsville
Huntsville, Alabama 35899

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Development of BATSE detector response matrices has been one of the major tasks under this delivery order. G. Pendleton led the joint UAH/MSFC effort to develop matrices for the BATSE large-area detectors (LADs) and spectroscopy detectors (SDs). The initial version (Rev 0) of the LAD matrices was completed in September 1990 and distributed to BATSE team members at MSFC and GSFC. Rev 0 of the SD matrices was completed the following month. These versions included 16 input energies and their parametrized angular response (assumed to azimuthally symmetric) was derived from Monte Carlo simulations at 10 zenith angles. With assistance from UAH graduate students T. Koshut and R. Mallozzi he refined the simulation geometry and expanded the input energy coverage to 64 values spanning the region from 5 keV to 100 MeV. The initial versions for both LADs and SDs (Rev 1) for flight data analysis were derived from these simulations and completed and distributed in March 1991.

Pendleton also supervised efforts by E. Roberts (MSFC) and Koshut to run Monte Carlo simulations of the atmospheric scattering effects and to develop suitable parametrizations of these results for use in BATSE analysis software. An important conclusion derived thus far has been that the angular dependence of the scattering varies rather slowly with energy, thereby allowing us to describe the scattered component with fewer parameters. Though much of this work has been done, completion is not expected until approximately two months after the BATSE launch. In the interim, the analysis software will continue to employ the single-scatter approximation for atmospheric scattering. Pendleton also worked with P. Lestrade (Mississippi St. U.) and M. Flickinger (UAH) on algorithms for in-flight evaluation of detector gain changes and the corresponding adjustments to channel-to-energy conversion parameters.

Pendleton served as BATSE representative to the GRO Mass Model Committee, attending the meeting in November 1990.

W. Paciesas served as BATSE Mission Operations (MOPS) Software Development Manager and also chaired the Level V Configuration Control Board for the MOPS software. Paciesas presented status reports on MOPS software development at the BATSE Science Team Meeting in November 1990 and at the GRO Mission Operations and Data Analysis Review in March 1991. The coding and unit testing of all 29 units is complete as of the expiration of this delivery order. The package was subjected to an extensive beta testing effort, involving Paciesas, Flickinger, W. Henze (TBE), C. Meegan (MSFC), R. Wilson (MSFC) and M. Finger (CSC). Table I summarizes the most important exercises of the software. Formal testing of the software has been delayed considerably due to the difficulty of writing test procedures which satisfy the MSFC Quality Assurance office requirements. Completion is not expected until July 1991. A waiver of QA approval has been requested by the BATSE MOPS manager and is expected to have a positive schedule impact if approved.

Paciesas conducted a study of the anomalous variation in width of SHER channel 64 and produced recommendations for correcting for this effect which have been incorporated in MOPS and data analysis software (see attachment A). These corrections, along with several other issues related to channel-to-energy conversion, were summarized in a memo to the BATSE team in February 1991 (see attachment B).

P. Moore provided administrative assistance in the MOPS software development effort and developed the BURST_DISPLAY unit. He also developed software for use with the BATSE NEWS service to be provided as part of the BATSE Data Analysis Software.

Pendleton and Paciesas collaborated with MSFC scientists to estimate BATSE sensitivity to gamma-ray lines and continuum, particularly with regard to detection of nearby novae. Pendleton presented papers summarizing these results at the International Symposium on Gamma-Ray Line Astrophysics, Saclay, France, in December 1990 [1,2] (see attachments C and D).

Paciesas continued to serve as scientific liaison overseeing development of the BATSE Spectral Analysis Software (BSAS) by GSFC. The BSAS Acceptance Review was held February 28-March 1, 1991. All 7 of the BSAS programs required by launch are considered complete, and 5 of the 6 programs desired by launch are considered complete. End-to-end functionality of the software has been demonstrated by GSFC, including transfer of data from MSFC, production and display of count spectra, model-fitting to count spectra, creation of photon spectra, and management of the necessary data bases. Build 2 of BSAS was released to UCSD and MSFC in December 1990, build 3 was released in March 1991, and build 4 is expected in early April 1991. D. Band (UCSD) conducted beta testing of BSAS during the period November 1990-April 1991. Beta testing at MSFC did not begin until March 1991 because of installation problems. Paciesas presented a status report on BSAS at the GRO Mission Operations and Data Analysis Review in March 1991.

Paciesas was responsible for coordinating involvement of BATSE Guest Investigators (GIs) in spectral analysis. Discussions of relevant issues were conducted during the BATSE Team Meeting in November 1990 and an agreement was reached with GIs E. Fenimore (LASL), D. Forrest (UNH), and E. Liang (Rice U.) regarding incorporation of GI-developed spectral analysis software into BSAS.

Paciesas continued to serve as the BATSE representative on the GRO Data Operations Group (GRODOG) and the GRO Users' Committee, attending meetings in October, 1990, and February, 1991. Paciesas provided BATSE inputs for the GRO Fellowship Program Announcement of Opportunity [3] which was issued in November 1990.

Paciesas was named to head the BATSE Occultation Analysis team for Mission Operations. He will oversee the effort to validate the MOPS occultation analysis software in-flight. Preliminary discussions have been conducted with GIs W. Wheaton and J. Ling (JPL) regarding their plans to develop algorithms for enhanced occultation analysis. Paciesas continued coordination of the related effort by MSFC and UCSD to develop software for modeling BATSE detector backgrounds. A. Harmon (USRA) and B. Rubin (USRA) are primarily responsible for the software design, with assistance from D. Gruber (UCSD) and Wheaton. The preliminary design is essentially complete and coding began in January 1991.

Paciesas presented a talk describing the BATSE occultation analysis capabilities and plans at the OSSE/EGRET Science Workshop in February 1991. Paciesas also represented BATSE at the OSSE Solar GI Meeting in January 1991, where he presented a talk describing the BATSE solar capabilities. Paciesas attended the Los Alamos Gamma Ray Burst Workshop in Taos, NM, during July 30-August 3 1990 and assisted G. Fishman (MSFC) in preparation of his paper for the workshop proceedings.

Support for BATSE operations during end-to-end tests was provided by Pendleton (ETE #5 at GSFC; ETE #6 & 7 at KSC), Flickinger (ETE #5 at GSFC; ETE #6 at KSC), Moore (ETE #5 at KSC), and subcontractor D. Rice (ETE #6 at KSC).

M. Flickinger has been responsible for monitoring the VLF receiving station at MSFC collecting data, and providing charts for cross-correlation with GOES data. Visual inspection of the VLF data has not resulted in any new short-timescale events which appear to be of non-solar origin. Flickinger visited Stanford U. in November 1990 to search archival VLF data for transient events coincident with gamma-ray bursts. Only one candidate event, of marginal significance, was found.

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[1] Fishman, G. J., Wilson, R. B., Meegan, C. A., Brock, M. N., Horack, J. M., Paciesas, W. S., Pendleton, G. N., Harmon, B. A., and Leising, M. "Detectability of Early, Low-Energy Gamma Rays from Nearby Novae by BATSE/GRO." To be published in the proceedings of the International Symposium on Gamma-Ray Line Astrophysics, Paris-Saclay, France, 10-13 December 1990.

[2] Pendleton, G. N., Paciesas, W. S., Fishman, G. J., Wilson, R. B., and Meegan, C. A. "Calculation of the Gamma-Ray Line Sensitivity of the BATSE Large Area Detectors on GRO." To be published in the proceedings of the International Symposium on Gamma-Ray Line Astrophysics, Paris-Saclay, France, 10-13 December 1990.

[3] *Gamma Ray Observatory Postdoctoral Fellowship Program*, NASA/GSFC Announcement of Opportunity, November 1990.

Table I

BATSE

MOPS Software Beta Testing

END-TO-END TEST SUPPORT:

* Oct. 2-4, 1989	#2	Command/control only
* Nov. 29-30, 1989	#2A	" " "
* Mar. 26-27, 1990	#3	" " "
* June 6-9, 1990	#4	Full operations (partial data delivery)
* July 20-21, 1990	#5	Activation
* Aug. 15-17, 1990	#6	Full operations (data delivery late)
* Oct. 30-Nov. 6, 1990	#7	" "
* Dec. 13-14, 1990	#7A	" "

REHEARSALS & TRAINING SESSIONS:

* Oct. 22-26, 1990	Tutorial
* Oct. 29-30, 1990	Rehearsal
* Feb. 7-12, 1991	Training session
* Feb. 20-22, 1991	Training session (redundant system)
* Mar. 5-8, 1991	Rehearsal (ETE 7 playback; redundant system)

ATTACHMENT A

W. Paciesas
January 9, 1991
(Rev 2)

Proposed changes to MOPS software in order to incorporate variable width of channel 64 in SHER/SHERB:

1) PACKET_DATA_HANDLER:

Before writing SHER data to daily dataset file, calculate the width of SHER channel 64 for each spectrum. Assuming that SHER channels 62 and 63 are each one linear channel in width and SHER channel 65 is two linear channels in width, we calculate the number of counts n expected in SHER channel 64 if it were one linear channel in width:

$$n(64) = (N(62) + N(63) + N(65)) / 4$$

where N is the actual number of counts in the corresponding SHER channel. This is equivalent to a simple linear interpolation. The actual width w of channel 64 is then

$$w(64) = N(64) / n(64) .$$

I suggest encoding this in the data as an I*2 word WIDTH64 corresponding to the fractional part of w in units of 1/16 of a channel, i.e.,

$$\mathrm{WIDTH64} = \mathrm{NINT}((w - 1) * 16)$$

where NINT represents the nearest integer function in FORTRAN. Statistical (or otherwise??) fluctuations might result in occasional instances where $w < 1$ or $w > 2$, in which case WIDTH64 should be constrained to be between 0 and 16:

$$\mathrm{WIDTH64} = 0 \quad \text{if} \quad w \leq 1$$

$$\mathrm{WIDTH64} = 16 \quad \text{if} \quad w \geq 2 .$$

WIDTH64 should then be stored in one of the auxiliary data words which are currently set to zero in SHER packets. I suggest using LEDAMP, which maps into the PACKET_DATA_HANDLER variable DATA_BUFFER2(16). The modified auxiliary data should then be written to the SHER_DATA files.

2) SPEC_DB_GENERATOR:

I assume that WIDTH64 will not change rapidly over the duration of the burst accumulation. Therefore, one value of WIDTH64 per detector will be considered valid for an entire IBDB and spare words in the INFO_IBDB_FDR should be used to hold these four values. I suggest deriving these values from the last SHER spectral accumulation prior to the burst trigger.

3) All MOPS units which need to convert SHER channels into linear channels:

The linear channel corresponding to a particular compressed channel must now be a real number. The real number w is calculated from WIDTH64 as

$$w = \mathrm{FLOAT(WIDTH64)}/16 \ .$$

Then the (non-integer) linear channel j corresponding to the lower edge of compressed channel i may be calculated as follows:

$j = i$	if	$i < 65$
$j = 65 + w$	if	$i = 65$
$j = 2*i - (65-w)$	if	$66 \le i < 129$
$j = 8*i - (833-w)$	if	$129 \le i < 193$
$j = 32*i - (5441-w)$	if	$i \ge 193$.

The average J of the linear channels contained in compressed channel i may be calculated as follows:

$J = i + 0.5$	if	$i < 64$
$J = 64.5 + 0.5*w$	if	$i = 64$
$J = 2*i - (64-w)$	if	$65 \le i < 128$
$J = 8*i - (829-w)$	if	$128 \le i < 192$
$J = 32*i - (5425-w)$	if	$i \ge 192$.

The width W of compressed channel i in linear channels is:

$W = 1$	if	$i < 64$
$W = 1 + w$	if	$i = 64$
$W = 2$	if	$65 \le i < 128$
$W = 8$	if	$128 \le i < 192$
$W = 32$	if	$i \ge 192$.

A complication occurs when integrating SHER spectra over time. For MOPS purposes it should be sufficient to assume that WIDTH64 does not change significantly over the integration interval. In that case, using the value of WIDTH64 for the first readout in the integration is probably adequate. However, an average over the accumulation interval could also be used and may have some advantages.

BATSE MEMO

To: Distribution

From: W. Paciesas

Date: February 11, 1991

Subject: Channel-to-Energy Conversion

The purpose of this memo is to summarize the process involved in conversion of BATSE compressed spectral channels into energy space. Various characteristics of the hardware which have not been properly understood previously have implications in this regard. I first summarize some conventions which have been used in all software developed at MSFC and which, for consistency, should be used in all BATSE data analysis. I then discuss the conversion of compressed channels to "linear" channels and, finally, the derivation of the energy from the "linear" channel.

I. Conventions

In BATSE data analysis software the following conventions are assumed:

1) Discriminator channel numbering starts with one.

2) All spectral information not derived from discriminators is derived from the MQT (charge-to-time converter) outputs. For these data types, channel numbering always begins with zero. Thus, HER spectra span the range 0 to 127, SHER spectra span the range 0 to 255, and MER spectra span the range 0 to 15. The corresponding range of linear channels also begins with zero. These conventions are also used in this memo.

3) In fitting spectra, the events in channel i are considered to span the range of real numbers from i to $i+1$. Thus, if a peak in the spectrum has its maximum counts in channel i and its other counts symmetrically distributed about channel i, then its peak centroid is considered to be located at $i+0.5$.

II. Converting Compressed Channels to Linear Channels (LADs)

The Large Area Detector (LAD) MQT outputs are compressed into 128 channels for HER and HERB data types and combined further into 16 channels for CONT, MER, and the pulsar data types. The original specification was to have the first 64 compressed channels each be one linear channel wide, the next 32 compressed channels each two linear channels wide, and the last 32 compressed channels each 8 linear channels wide, thus spanning a digital dynamic range of 384 linear channels.

The actual compression for HER channels differs slightly from our original specifications in that there are 65 HER (compressed) channels which are one linear channel wide and only 31 HER channels which are two linear channels wide. The digital dynamic range is thus equivalent to 383 linear channels. However, MQT saturation typically occurs before channel 383 is reached, so that the integral (overflow) channel is typically lower than 127 in HER spectra. Furthermore, the MQT saturation effect has some intrinsic spread on the low-energy side, so that several channels below the nominal overflow channel may also be contaminated by overflow events. Users of any data analysis products which access HER spectra directly should be made aware of this fact and these channels should be eliminated from further analysis in most cases.

The linear channel j corresponding to the lower edge of compressed channel i may be computed as

$$j = i \qquad \text{if} \qquad i < 65$$

$$j = 2*i - 65 \qquad \text{if} \qquad 65 \le i < 96$$

$$j = 8*i - 641 \qquad \text{if} \qquad i \ge 96 .$$

The average J of the linear channels contained in compressed channel i may be calculated as

$$J = i + 0.5 \qquad \text{if} \qquad i < 65$$

$$J = 2*i - 64 \qquad \text{if} \qquad 65 \le i < 96$$

$$J = 8*i - 637 \qquad \text{if} \qquad i \ge 96 .$$

Note that for highest accuracy J should be treated as a real number. The width W of compressed channel i in linear channels is

$$W = 1 \qquad \text{if} \qquad i < 65$$

$$W = 2 \qquad \text{if} \qquad 65 \le i < 96$$

$$W = 8 \qquad \text{if} \qquad i \ge 96 .$$

III. Converting Compressed Channels to Linear Channels (SDs)

The Spectroscopy Detector (SD) MQT outputs are compressed into 256 channels for SHER, SHERB, and STTE data types, and may be combined further into 16 channels for pulsar data types. The original specification was to have the first 64 compressed channels each be one linear channel wide, the next 64 compressed channels each two linear channels wide, the next 64 compressed channels each 8 linear channels wide, and the last 64 compressed channels each 32 linear channels wide, thus spanning a digital dynamic range of 2752 linear channels.

Under normal lab conditions, most SDs appear to be consistent with this scheme. However, at least two modules have been observed to show a variation in the width of compressed channel 64 with time, apparently temperature-dependent. Although a thorough investigation of test & calibration data has yet to be done, clear evidence exists for variations in the width of channel 64 from one linear channel to two linear channels over time periods as short as a few hours. After discussing the problem with the hardware designer we are confident that the width cannot drift outside this range. It is not clear at this point how significant the effect will be under orbital conditions.

Nevertheless, the software has been modified to correct for variations if they do occur. The following discussion summarizes what has been done in the MOPS software and what the implications are for subsequent analysis.

Before writing SHER data to daily dataset files, MOPS software calculates the width of SHER channel 64 for each spectrum. Since SHER channels 62 and 63 are each one linear channel in width and SHER channel 65 is two linear channels in width, we calculate the number of counts n expected in SHER channel 64 if it were one linear channel in width:

$$n(64) = (N(62) + N(63) + N(65)) / 4$$

where N is the actual number of counts in the corresponding SHER channel. This is equivalent to a simple linear interpolation. The actual width w of channel 64 is then

$$w = N(64) / n(64) .$$

This is encoded in the data as an I*2 word *WIDTH64* corresponding to the fractional part of w in units of 1/16 of a channel, i.e.,

$$WIDTH64 = NINT((w - 1) * 16)$$

where *NINT* represents the nearest integer function in FORTRAN. Statistical (or otherwise??) fluctuations might result in occasional instances where $w < 1$ or $w > 2$, in which case *WIDTH64* is constrained to be between 0 and 16:

$$WIDTH64 = 0 \quad \text{if} \quad w \le 1$$

$$WIDTH64 = 16 \quad \text{if} \quad w \ge 2 .$$

WIDTH64 is stored in one of the auxiliary data words which are currently set to zero in SHER packets and the modified auxiliary data are written to the SHER_DATA files. A union within the MOPS structure /DD_HER_AUX_DR/ has been created for this purpose.

SHERB data are handled by assuming that *WIDTH64* will not change rapidly over the duration of the burst accumulation. Therefore, one value of *WIDTH64* per detector is considered valid for the burst, namely that of the last SHER spectral accumulation prior to the burst trigger. The MOPS structure /INFO_IBDB_FDR/ written to the INFO_GRO_IBDB and INFO_CAL_IBDB files has been modified to hold these four values.

The duration over which *WIDTH64* can ultimately be assumed to remain constant is debatable at this point. My recommendation for the time being is to treat it the same way as gain drifts in general: integrations as long as 15 minutes or so are probably safe, but use of data on timescales of the order of one orbit (90 minutes) will probably require rebinning to avoid degradation of spectral resolution.

Conversion from compressed channels to linear channels now requires real number arithmetic. First, the real number w is calculated from *WIDTH64* as

$$w = FLOAT(WIDTH64)/16 .$$

Then the (non-integer) linear channel j corresponding to the lower edge of compressed channel i may be calculated as

$$
\begin{array}{lll}
j = i & \text{if} & i < 65 \\
j = 65 + w & \text{if} & i = 65 \\
j = 2*i - (65-w) & \text{if} & 66 \le i < 129 \\
j = 8*i - (833-w) & \text{if} & 129 \le i < 193 \\
j = 32*i - (5441-w) & \text{if} & i \ge 193 \,.
\end{array}
$$

The average J of the linear channels contained in compressed channel i is

$$
\begin{array}{lll}
J = i + 0.5 & \text{if} & i < 64 \\
J = 64.5 + 0.5*w & \text{if} & i = 64 \\
J = 2*i - (64-w) & \text{if} & 65 \le i < 128 \\
J = 8*i - (829-w) & \text{if} & 128 \le i < 192 \\
J = 32*i - (5425-w) & \text{if} & i \ge 192 \,.
\end{array}
$$

The width W of compressed channel i in linear channels is

$$
\begin{array}{lll}
W = 1 & \text{if} & i < 64 \\
W = 1 + w & \text{if} & i = 64 \\
W = 2 & \text{if} & 65 \le i < 128 \\
W = 8 & \text{if} & 128 \le i < 192 \\
W = 32 & \text{if} & i \ge 192 \,.
\end{array}
$$

These considerations also imply that the digital dynamic range is actually $2752-w$ linear channels. The MQT saturation also typically occurs at a lower channel for the SDs as well as the LADs, in which case the valid range of linear (and compressed) channels is less than the allowed range.

IV. Conversion of linear channel number to energy

Extensive analysis of test and calibration data has shown that the dependence of energy E on linear MQT channel j is adequately described for both LADs and SDs an equation of the form

$$E = A + B*j + C*j^{1/2} \,, \qquad (1)$$

where A, B, and C are determined by least-squares fits to calibration data. The MOPS software is designed to be able to monitor the gain continuously by measuring the centroids of background lines on timescales as short as permitted by the HER/SHER readout schedule (expected to be ~5 minutes).

On-orbit analysis would thus require measurement of at least three background features in order to specify all three parameters uniquely for a given interval. For the LADs, and most likely also for the SDs, we do not expect to be able to distinguish a sufficient number of line features on short enough timescales to permit recalculation of all three parameters. Furthermore, the likely background features are likely to be at higher energies, where the dependence of some fit parameters is relatively weak. Therefore, we chose to recalculate *A*, *B*, and *C* in MOPS software by a perturbation technique. We measured the changes in *A*, *B*, and *C* for small gain changes within the expected operating ranges of the detectors and, using perturbation methods, parametrized the changes in *A*, *B*, and *C* resulting from small changes in the centroid of expected background lines. If more than one background feature is usable, the parameters will still be determined using the same formulae, using least-squares minimization to find the "best fit."

Using this technique, we will calculate *A*, *B*, and *C* for each detector as part of MOPS analysis as often as needed to follow gain variations. The results will be stored in a set of calibration files which will be archived to optical disk along with the packet data. The MOPS software will also maintain a history of the most recent several weeks of gain calibration data on magnetic disk. Records from these calibration files are included as needed in secondary data bases. For example, they are written to the INFO_CAL_IBDB file in the IBDB as *GAIN_FUNCT(1:3)* in the structure /INFO_CAL/ (although the structure allows room for four gain parameters, we currently believe that three are sufficient; the fourth should be ignored, and will be set to zero in the IBDB files).

Some concerns have been expressed regarding the correct incorporation of the UCSD measurements of the NaI light output linearity into this process. Our approach here is twofold:

1) The relatively smooth variation in light output at energies above the K-edge is implicitly included in equation 1. We do not expect to need further corrections for this effect.

2) Corrections for the more complex variations in the light output near the K-edge will be included in the first release version of the detector response matrices.

3) The fall-off in light output at low energies is difficult to distinguish from electronic threshold effects. Our tentative plan is also to include low-energy corrections in the next release of the detector response matrices. This implies that the set of response matrices will have an MQT-threshold dependence. The feasibility of this approach is still being evaluated.

DETECTABILITY OF EARLY, LOW-ENERGY GAMMA RAYS FROM NEARBY NOVAE BY BATSE/GRO

G.J. Fishman, R.B. Wilson, C.A. Meegan
M.N. Brock, J. M. Horack
NASA/Marshall Space Flight Center, AL 35812

W.S. Paciesas, G.N. Pendleton,
Physics Dept., University of Alabama in Huntsville

B.A. Harmon
Universities Space Research Association

M. Leising
Naval Research Laboratory, Washington D.C.

ABSTRACT

The Burst and Transient Source Experiment (BATSE) on the Gamma Ray Observatory, having an all-sky observing capability and high sensitivity in the low energy gamma-ray region, has a reasonable chance of detecting emission from a nearby nova within the first few hours of its outburst.

INTRODUCTION

The energy source of classical novae is well-understood as a thermonuclear runaway in CNO material on an accreting white dwarf in a binary system. Short-lived, positron-emitting nuclei are produced in large quantities. Their subsequent decay helps power the ejection of the envelope and produces large fluxes of annihilation radiation in the burning region. However, there is still great uncertainty in the hydrodynamics of the highly unstable, expanding envelope. The emerging fluxes of annihilation radiation and the Comptonized spectra from several possible models of novae have been calculated[1,2]; figure 1 shows the fluxes from key isotopes based on one of these models.

The amount of mixing and density fluctuations in the envelope significantly affect the magnitude and evolution of the emerging annihiation radiation. Also, since the envelope is still very thick during the decay of most of the radioactive nuclei considered here, many of the 511 keV annihilation photons are Compton scattered to lower energies before they emerge. This results in a hard spectrum, peaking in the energy region between 20 to 100 keV. (It should be noted that the highly Comptonized spectrum from SN1987A was detected much sooner than expected, now thought to be due to deep mixing in the expanding envelope.)

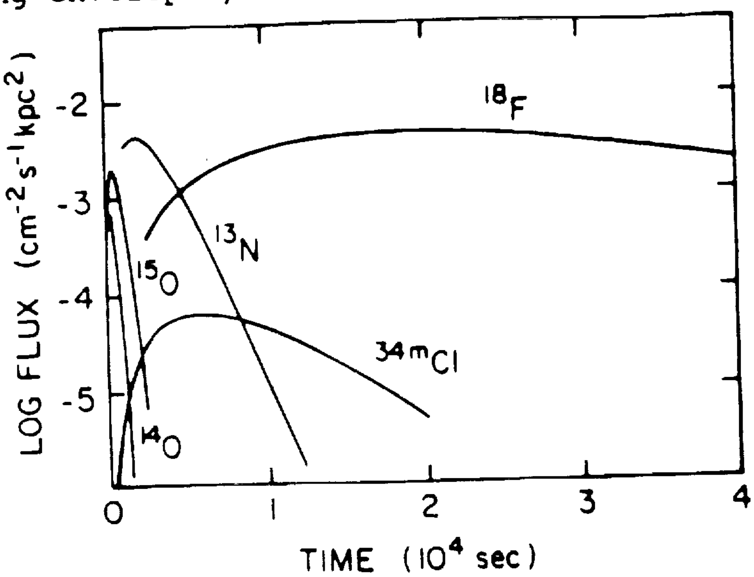

Fig. 1. Emerging flux of 511 keV photons from a nova, based on Model 1 in Ref. 1.

DETECTABILITY

BATSE is designed primarily for the observation of gamma-ray bursts. It can also detect and study longer-lived sources such as that described here. The experiment consists of eight independent detector modules located at the corners of the GRO spacecraft. Each module contains a large area detector (LAD) and a spectroscopy detector (SD). The LADs are 1.27 cm thick and have an uncollimated area of 2025 cm^2 each. The LADs cover a nominal energy range from 25 keV to 1.7 MeV. A transient source in this range, such as that expected from a nearby nova, can be detected by BATSE in two different ways. The first method uses earth occultation; a description of the sensitivity of BATSE using this technique has been described previously[3,4]. We assume that the nova will be observed in the energy bands shown in Table 1 and have estimated the expected backgrounds in those bands. For two detectors with axes 35 deg from the direction of the nova, each occultation step would produce a signal of the indicated statistical significance. There will be two occultation steps observed during each 90 minute orbit, providing a good sample of the build-up and decay of the emission from the nova. Approximately 10% of the sky, near the GRO orbit poles, will not be observable by the occultation technique.

The second observational technique would be to use background samples from the same portion of the GRO orbit as the nova observation, but with a time difference of a day or more. This technique is being used successfully in several studies with data from the gamma-ray spectrometer on the SMM. Since a longer time base can be used for both source and background observations, the statistical uncertainties can be reduced considerably. The signals from multiple detectors can be compared for consistency with that expected from a distant point source. However, the technique is subject to potentially larger systematic errors which are instrument-unique and are difficult to estimate prior to launch.

The rate of nearby novae is uncertain due to selection effects and unknown amounts of obscuration. A reasonable estimate of the rate of novae within 1 kpc of the earth is one per five years, with an uncertainty of about a factor of two. This is of the same order as the GRO lifetime, which has a similar uncertainty.

Table I - Calculated occultation signal from a nova @ 1 kpc, observed by two BATSE detectors, 35 deg off-axis and assuming 300 s backgrounds.

E (keV)	Signal (sigma)
30- 50	2.8
50-100	11.0
100-200	10.5
200-500	8.3
511 keV line	2.2

CONCLUSION

The promising observation of evolving gamma-ray spectra from a nearby nova would yield important new information on the early hydrodynamics of novae as well as the abundances of several radioactive isotopes. The short-lived emission requires wide-field or all-sky detectors, such as those of the BATSE/GRO.

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CALCULATION OF THE GAMMA-RAY LINE SENSITIVITY OF THE BATSE LARGE AREA DETECTORS ON GRO

G. N. Pendleton, W. S. Paciesas, University of Alabama in Huntsville

G. J. Fishman, R. B. Wilson, C. A. Meegan,
NASA/Marshall Space Flight Center

ABSTRACT

The gamma-ray line sensitivity of the BATSE detectors depends primarily upon the characteristics of the detectors' response and the nature of the backgrounds observed by the instruments. Using the example of the detectability of prompt annihilation radiation from nearby novae, the detector response characteristics and data analysis tools relevant to gamma-ray line and continuum sensitivity determination will be presented. Sensitivities to gamma-ray lines at various energies will be presented.

INTRODUCTION

The BATSE large area detectors (LAD's) are designed primarily for the measurement of the hard X-ray continuum of gamma-ray bursts. The LAD's are NaI(Tl) disks 25 cm in radius and 1.27 cm thick. The instrument described in detail elsewhere[1,2] is optimized for the 50 to 300 keV energy range and full sky coverage. However it produces data binned into channels several times narrower than the detector resolution making the search for line features possible. The gamma-ray line and continuum sensitivities presented here are calculated using simulation generated detector response matrices and an estimate of the background expected in orbit.

LAD DETECTOR RESPONSE MATRICES

The detector response matrices are generated using a modified version of EGS3[3] and a detailed geometry code written by the author specifically for the BATSE instrument. Their accuracy has been verified by extensive comparison with calibration data. The response is strong from 30 to 200 keV but drops off significantly at higher energies. At 500 keV a significant fraction of the photons that do interact in the crystal fail to deposit all their energy resulting in a significant Compton tail in the detector response at this energy.

THE BACKGROUND ESTIMATION

The background is estimated from balloon flight data[4] obtained using modified

LAD's combined with the detector's estimated response to the low energy diffuse cosmic background flux[5]. The detectors were facing upward so the background is considered to be that observed by a sky viewing detector. The low energy diffuse cosmic background is unable to penetrate the atmosphere to balloon altitudes. Therefore a component due to the cosmic background not observed by the detectors at balloon altitudes but detected in orbit was added to the balloon flight data for the background estimate.

CALCULATED SENSITIVITIES

Table 1 shows the line flux observable at a 3 sigma significance by an LAD for 100 sec. and 300 sec. exposures at various energies. These significances are for one LAD viewing the flux face on. A 300 sec. exposure could be obtained for a steady source using earth occultation. These sensitivities apply to a gamma-ray line that is not accompanied by continuum flux that is significant compared to the background flux.

Table 2 shows the LAD sensitivities to line features superimposed on a typical gamma-ray burst continuum for three different burst continuum fluences. The sensitivities in this table are given in seconds. These are the observation times required to obtain a 3 sigma significance measurement of a line feature whose equivalent width equals the FWHM of the detector response at that energy. The significance calculation is based on the assumption that a simple background subtraction is performed to extract the line feature using background intervals distributed around the line feature whose sum total width equals the FWHM of the detector at the given energy. These background intervals consist of the background continuum plus the burst continuum.

Table 3 shows the sensitivity in sigma above background of one LAD viewing the flux face on to the continuum produced by a typical nova[1,6] at 1 Kpc. 5 hours after ignition for three different integration times. The two shorter observations could be made using earth occultation. The longer observation would require the

TABLE 1

Line Energy (keV)	3 Sigma Line Strength (1sec)	3 Sigma Line Strength (300sec)
20	1.07	6.20E-2
30	2.19E-1	1.26E-2
60	9.49E-2	5.46E-3
100	6.59E-2	3.61E-3
200	6.45E-2	3.72E-3
500	1.32E-1	7.63E-3

Line Strengths in ph/cm^2/sec

use of a background estimation technique. Table 4 is the same as table 3 except that it applies to two LAD's viewing the flux at 35.26 degrees to the detector normal; this situation is not unlikely for the BATSE instrument.

The LAD's will provide measurements of the continuum flux from nearby novae but they cannot measure the 511 keV line flux as readily[1]. They will be able to measure line features in strong bursts. They will also be able to produce measurements hard X-ray continuum spectra of nearby novae that should provide constraints on nova model parameters.

TABLE 2

Sensitivites for Line Features in Gamma-Ray Bursts

Line Energy (keV)	Burst Strengths:	3 Sigma Observation Times(sec.) 10E-4 erg/cm^2	10E-5 erg/cm^2	10E-6 erg/cm^2
20		2.2E-3	3.8E-2	3.02
30		6.0E-4	7.2E-3	0.18
60		3.4E-4	3.6E-3	6.2E-2
100		3.7E-4	3.9E-3	5.8E-2
200		6.6E-4	6.9E-3	0.11
500		1.1E-2	8.3E-2	1.59

TABLE 3

Nova Continuum Sensitivities
in Sigma above Background
One Detector 0 Degrees

Energy Range	Exposure Duration 100 sec	300 sec	600 sec
20-30	0.28	0.48	3.32
30-50	1.35	2.35	3.32
50-100	5.40	9.36	13.24
100-200	5.01	8.67	12.27
200-500	3.76	6.52	9.22

TABLE 4

Nova Continuum Sensitivities
in Sigma above Background
Two Detectors 35.26 Degrees

Energy Range	Exposure Duration 100 sec	300 sec	600 sec
20-30	0.35	0.60	3.93
30-50	1.61	2.78	3.94
50-100	6.37	11.02	15.60
100-200	6.07	10.52	14.87
200-500	4.84	8.39	11.86

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16. Abstract

Miscellaneous tasks related to the development of the Burst and Transient Source Experiment on the Gamma Ray Observatory and to collection, analysis, and interpretation of data from the MSFC Very Low Frequency transient monitoring program were performed. The results are summarized and relevant references are included.

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CORP: Alabama Univ., Huntsville. CSS: (Dept. of Physics.)

SAP: Avail: CASI HC A03/MF A01
CIO: UNITED STATES
MAJS: /*GAMMA RAY ASTRONOMY/*GAMMA RAY BURSTS/*GAMMA RAY OBSERVATORY/*VERY LOW
FREQUENCIES
MINS: / COMPUTER PROGRAMS/ DATA PROCESSING/ GAMMA RAY SPECTRA/ NOVAE/ PHOTONS
ABA: Author

ABS: Miscellaneous tasks related to the development of the Burst and Transient Source Experiment on the Gamma Ray Observatory and to collection, analysis, and interpretation of data from the MSFC Very Low Frequency transient monitoring program were performed. The results are summarized and relevant references are included.

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